A PROPOSED STUDY EXAMINING INDIVIDUAL DIFFERENCES IN TEMPORAL PROFILES OF CARDIOVASCULAR RESPONSES TO HEAD DOWN TILT DURING FLUID LOADING

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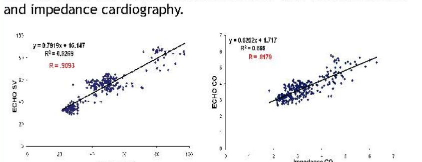
Susceptibility of healthy astronauts to orthostatic hypotension and presyncope is exacerbated upon return from spaceflight. The effect of altered gravity during space flight and planetary transition on human cardiovascular function is of critical importance to maintenance of astronaut health and safety. Hypovolemia, reduced plasma volume, is suspected to play an important role in cardiovascular deconditioning following exposure to spaceflight, which may lead to increased peripheral resistance, attenuated arterial baroreflex, and changes in cardiac function. A promising countermeasure for post-flight orthostatic intolerance is fluid loading used to restore lost plasma volume by giving crew salt tablets and water prior to re-entry. The main purpose of the proposed study is to define the temporal profile of cardiac responses to simulated 0-G conditions before and following a fluid loading countermeasure. 8 men and 8 women will be tested during 4 hour exposures at 6° head down tilt (HDT). Each subject will be given two exposures to HDT on separate days, one with and one without fluid loading (one liter of 0.9% saline solution). Stand tests (orthostatic stress) will be done before and after each HDT. Cardiac measures will be obtained with both impedance cardiography and echo ultrasound.

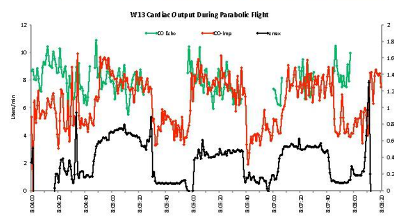
Buckey, et al. (1996) reported that up to 64% of astronauts experience post-flight orthostatic hypotension. Meck, et al. (2001) found that 14 day flights resulted in 20% of astronauts experiencing presyncope, whereas the rate rises to 83% following longer duration missions (129-190 days). Six-degree head-down bed rest (HDBR) has been shown to be an analogue to spaceflight as it removes the gravity vector directed from the head to the feet and induces a similar cephalad fluid shift as seen in spaceflight (Fortney Schneider and Greenleaf 1996; Charles and Bungo 1991).

Currently, echocardiography is the only non-invasive method for measuring cardiac responses during exposure to microgravity. Trans-thoracic impedance cardiography provides an alternative method for observing cardiac responses that can be measured continuously. The major advantages offered by this method are that the monitoring equipment is quick and relatively easy to setup , is portable, noninvasive and unobtrusive. Our highest priority is to know the time course of effects of fluid and salt loading on cardiac pre-load, so that we in the future can advise the astronauts as to how long before re-entering the atmosphere is optimal from a fluid loading point of view, which is the point in time, when SV peaks.

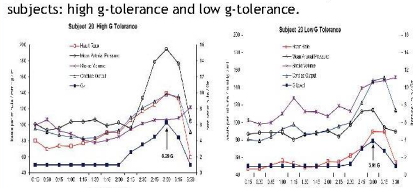
Researchers at NASA Ames have extensive experience in monitoring human physiology in extreme environments that include spaceflight, parabolic flight, chronic exposures to hyper-gravity in a centrifuge, and laboratory studies of orthostatic tolerance (Cowings, et al. 2007). In one study participants were exposed to 60° head up tilt and other autonomic nervous system (ANS) function tests. The figure below shows a high correlation for stroke volume and cardiac output measured with echo ultrasound and impedance cardiography.



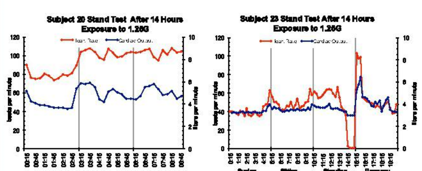
In a study conducted on the Zero-G aircraft cardiac responses were recorded from participants during 0-G parabolas. Simultaneous measures were obtained with echo ultrasound and impedance equipment. Although echo measures were difficult to record during the micro-g phases of parabolic flight due to movement of the heart, there was a good correlation between echo and impedance measures as g-levels increased.



In another study subjects were given G-tolerance tests before and after prolonged 22 hour exposures at 1.25G in a centrifuge. The figures below show differences in cardiovascular responses of two subjects: high g-tolerance and low g-tolerance.



Subject 20, high g-tolerance, showed larger magnitude changes in heart rate and mean arterial pressure than subject 23. but no significant differences were observed cardiac output and stroke volume. However, after 14 hours of exposure at 1.25g, there was a clear difference in cardiac output, stroke volume and heart rate compensatory responses to an orthostatic stress test. Subject 23 experienced syncope while attempting to stand.



1. Define the temporal profile of cardiac responses to 6° Head Down Tilt (HDT) with fluid loading and without fluid loading.
2. Examine HDT effects on orthostatic tolerance with and without fluid loading.
3. Examine individual differences (e.g., gender and age effects) to HDT and fluid loading.
4. Correlate bio-impedance and echo ultrasound measures obtained during HDT and orthostatic stress tests.

Participants: Eight men and eight women (unpaid healthy volunteers) between the ages of 18 and 65 will participate in this study. Subjects will be instructed to limit their dietary salt intake for 24 hours before each session (low salt = 50 - 75 mmol/24 hrs).

Each participant will be evaluated during two separate 4-hour 6° Head Down Tilt (HDT) tests (1 test without fluid loading and 1 test without fluid loading). Order of tests will be counterbalanced. There will be a seven day interval between each test. All testing will occur in the morning hours between 8AM and 12PM. The standard fluid loading protocol used with astronauts will be followed for this study: participants will drink one liter of 0.9% saline solution during their second exposure to HDT.

Before and following each HDT test participants will be tested for orthostatic tolerance. Stand tests will include: 3 minutes supine, 3 minutes sitting, and 3 minutes standing.

Echocardiography will be recorded during each stand test and at 30 minute intervals (3-minute duration) throughout the HDT tests.

Measures: Below is a list of 20 physiological variables recorded continuously during 4 Hours HDT tests and stand tests.

LFPV: Left finger pulse vol.	LL EMG: left leg muscle
RFPV: Right finger pulse vol.	RL EMG: right leg muscle
RR: Respiration Rate	SBP: Systolic blood pressure
HR: Heart Rate	DBP: Diastolic blood pressure
SCL: Skin Conductance Level	MAP: Mean arterial pressure
TEMP: Left hand temperature	Zo: Thoracic fluid volume
PVol 1: Blood flow left foot	SV: Stroke volume
PVol 2:.Blood flow right foot	CO: Cardiac output
LA EMG: left arm muscle	TPR: Total peripheral resistance
RA EMG: right arm muscle	Vagal Tone

Echocardiography data will be collected for 3 minute periods every 30-minutes throughout the 4-hour HDT tests. We will select data of all other physiological variables at the same time periods as echo data. These data will be analyzed with a repeated measures ANOVA: 2 conditions (HDT with fluid loading and HDT without fluid loading) and 8 time periods per test.

ANOVA will also be used to analyze data collected during stand tests: 2 stand tests (pre and post HDT, and 3 conditions (supine, sitting, standing) for each test.

Post-hoc comparisons will be performed on significant main effects and interactions.

Cowings PS, Toscano WB, De Roshia C, Taylor B, Hines A, Bright A, Dodds A. Converging indicators for assessing individual differences in adaptation to extreme environments. *Aviat. Space, & Environ. Med.* 2007, 78:5, Section II B195-B215.

Buckey, JC, Lane, LD, Levine BD,Watenpaugh DE, Wright SJ, Moore WE, Gaffney FA, Blumqvist CG, Orthostatic intolerance after spaceflight, *J. Appl. Physiol.* 1996; 81:7-18.

Charles, JB, Bungo, MW. Cardiovascular physiology in space flight. Experimental Gerontology, 1991, 26: (issues 2-3), 163-168.

Fortney SM, Schneider VS and Greenleaf JE. The physiology of bed rest. In: Handbook of Physiology,Environmental Physiology, Bethesda, MD: American Physiology Society, 1996, p. 889-939.

Meck, JV, Waters WW, Ziegler MG, deBlock HF, Mills PJ, Robertson D, Huang, Pl. Mechanisms of postspaceflight orthostatic hypotension: low {alpha} 1-adrenergic receptor responses before flight and central autonomic dysregulation postflight. Am. J Physiol Heart Circ . 2004; 286: H1486H1495.

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